Q – 1. (a) Define the term work as used in physics. Explain with examples that work can be positive, negative or zero.

(b) Define the unit of work .

Answer :

WORK (W)

In ordinary language the word " work " means almost physical or mental activity but in physics it has only one meanings :

Work is said to be done only when a force (F) produces motion.

The work done by a force (F) on a body is defined as the product of the force (F) and the distance (S or d) moved by the body in the direction of the force (F).

Work is a scalar quantity.

$$\text{Work} = \text{Force} \times \text{Distance moved in the direction of the force}$$

$$W = F\,S$$

$$\boxed{W = F\,S} \qquad (\text{EQ.1})$$

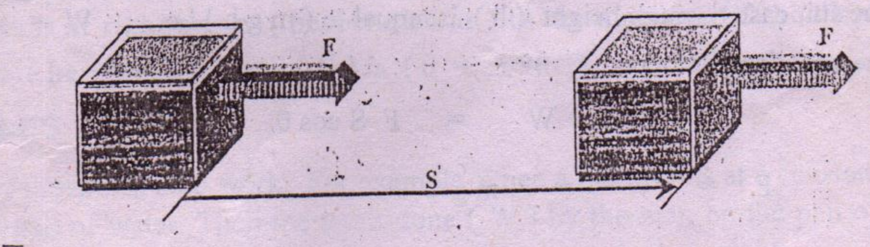

Fig.(1)
Work done by a force (F) in displacement (S) in the direction of force

Fig. (1) shows a constant force (F) applied to a body and displaces a body through a distance (S or d) in its own direction.

EXAMPLES

- When an engine moves a train along a railway line , it is said to be doing work.
- Horse pulling a cart is also doing work.
- A man climbing the stairs of a house is doing work.

FORMULA FOR WORK DONE WHEN A BODY MOVES AT AN ANGLE TO THE DIRECTION OF FORCE

Many a times, the force makes an angle (θ) with the direction of the displacement. If the angle between the displacement ($\vec{S}$) and the force ($\vec{F}$) is (θ) (see Fig..2), then the component of the force in the direction of the displacement is ($F\cos\theta$) and the work done by the force ($\vec{F}$) is defined by the equation.

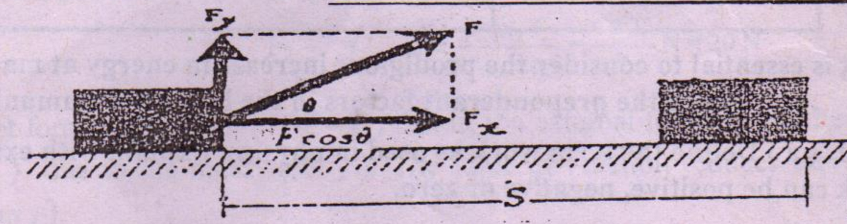

Fig. (2)

$$W = F\cos\theta \times S$$

$$W = F S \cos\theta$$

$$\boxed{W = F S \cos\theta} \qquad \text{(EQ. 2)}$$

POSITIVE WORK

That type of work in which the force has a component in the same direction as the displacement, i.e. the angle (θ) between ($\vec{F}$) and ($\vec{S}$) lies between (0°) and ($+90^\circ$) is called positive work.

EXAMPLES

1. Fig.(1 or fig 2) illustrates positive work. For example the force required to lift a suitcase of mass (m) is equal to its weight ($w = m g$), Then work done (W) in lifting the suit case through height (h) is equal to (m g h) i.e $W = m g h$

Using the equation

$$W = F S \cos\theta$$

Here $F = w = m g$

$$S = h$$

In particular if $\theta = 0^\circ$ $\quad W = m g h \cos 0^\circ$

$$W = m g h (1) \qquad (\cos 0^\circ = 1)$$

$$\boxed{W = m g h}$$

2. Work done in stretching spring is positive work done.

3. When a body falls freely under the action of gravity , then the work done is positive.

4. To lift the bucket , force has to be applied vertically upward and bucket also moves upwards i.e. the work done is positive.

NEGATIVE WORK

That type of work in which the force has a component in the opposite direction to the displacement, i.e. the angle (θ) between ($\vec{F}$) and ($\vec{S}$) lies between (90°) and (180°) is called negative work.

EXAMPLES

1. For example, when a body moves against the force of friction on a horizontal plane, the work done by the force of friction is negative.

Using the equation

$$W = F\,S\cos\theta$$

In particular if $\theta = 180^\circ$

$$W = F\,S\cos 180^\circ$$

$$W = F\,S(-1) \qquad (\cos 180^\circ = -1)$$

$$W = -F\,S$$

$$\boxed{W = -FS}$$

2. Work done by friction on a body sliding down an inclined plane is negative.

3. Work done by the gravitational force on the body being lifted up is negative.

ZERO WORK

That type of work in which either the displacement ($\vec{S} = \vec{0}$) OR the direction of the force is at right angle (perpendicular) to the direction of the displacement i.e. the angle between ($\vec{F}$) and ($\vec{S}$) is ($\theta = \pm 90^\circ$) is called zero work.

EXAMPLES

1. Fig.(3) illustrates zero work. For example When a man walks at a constant velocity carrying a pail of water, Then the work done (W) by the man on the pail of water is equal to zero. i.e $W = 0$

Using the equation

$$W = F\,S\cos\theta$$

In particular if $\theta = 90^\circ$

$$W = F\,S\cos 90^\circ$$

$$W = F\,S(0) \qquad (\cos 90^\circ = 0)$$

$$W = 0$$

Thus the work done (W) by the man on the pail of water is zero.

$$W = 0$$

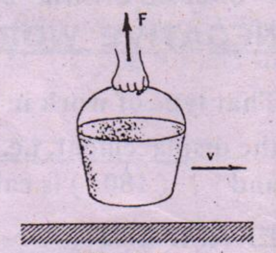
Fig (3)
Shows Zero work

Since the force ($\vec{F}$) that the man exerts on the pail of water and the displacement ($\vec{S}$) are mutually perpendicular. There is no component of the applied force in the direction of the displacement. Although the man holding the pail of water or carrying it horizontally does no work on it, the muscles in his arm do stretch and contract and thus some work is done internally, which may result in fatigue. But internal work, in physics, is not considered as work.

2. Fig.(.4) illustrates zero work. For example, a man may completely exhausted in trying to push a stationary wall , but since there in no displacement (the wall does not move) , the work done by the man on the wall is equal to zero. i.e

$$W = 0.$$

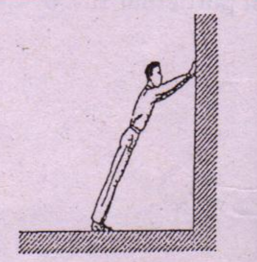
Fig (4)
Shows Zero work

Using the equation $W = F\ S \cos\theta$

But $S = 0$ (wall is not displaced)

$$W = F\ (0) \cos\theta$$

$$W = 0$$

3. A weight lifter in holding a mass of (100 kg) on his shoulders for (40 sec) then the work done by the weight lifter is equal to zero i.e. $W = 0$.

Using the equation $W = F\ S\ \cos\theta$

But $S = 0$ (weight lifter is at rest)

$$W = F\ (0)\ \cos\theta$$

$$W = 0$$

4. Work done by centripetal force on a body in circular motion is equal to zero i.e. $W = 0$.

5. Work done by the earth gravitational force in keeping the moon in its orbit (assumed perfectly circular) is equal to zero i.e. $W = 0$.

6. Work done by the man carries a suitcase horizontally , he does NO work i.e. $W = 0$ in respect of gravity because the force of gravity acts vertically downward and the angle between the displacement of the suitcase and the direction of the force becomes ($\theta = 90°$).

SI UNIT OF WORK

The SI unit of force is newton (N) and that of distance is metre (m), so the unit of work is newton metre which is written as (N-m). This unit of work is called joule denoted by (J).

3. A person pushing a trolley. If the force (F) exerted by him on the trolley is (30 N) and the trolley moves a distance of (5 m) in the direction of the force, calculate the work done by the force on the trolley.

SOLUTION

Force exerted by the person on the trolley , $F = 30\ N$

Distance covered by the trolley , $S = 5\ m$

Work done by the force on the trolley , $W = ?$

Using the equation

$$W = F\ S$$

$$W = (30\ N)(5\ m) = 150\ N\,m$$

$$\boxed{W = 150\ J}$$

4. A man is pulling a object of weight (20 N)with a force of (30 N) with a rope which is making an angle of (30 degrees) with the direction of motion of the object. The object moves (20 m) along the ground. Calculate the work done by the man in pulling this object.

SOLUTION

Weight of the object , $w = m\,g = 20\ N$

Force applied by the man, $F = 30$

Distance covered by the object , $S = 20\ m$

Angle between the direction of the force and the direction of the displacement ,

$$\theta = 30^{\circ}$$

Work done by the man , $W = ?$

Using the equation

$$W = F\ S\ \cos\theta$$

$$W = (30\ N)(20\ m)(\cos 30^{\circ})$$

$$W = (30\ N)(20\ m)(~~0.5~~)\ 0.866$$

$$W = 300\ N\,m \qquad (\cos 30^{\circ} = 0.5$$

5. A bullet of mass (30 gram) travels at a speed of (1500 ms^{-1}) . Calculate its kinetic energy.

SOLUTION

Please note that : (1 kg = 1000 gram = 10^3 gram)

Please note that : (1 gram = 10^{-3} kg)

Mass of the bullet , m = 30 gram = $\frac{30 \text{ gram}}{1000}$ = 0.03 kg

Speed of the bullet , v = 1500 ms^{-1}

Kinetic energy of the bullet , K . E = ?

Using the equation K.E = $\frac{1}{2}mv^2$

$$K.E = \frac{1}{2}(0.03 \text{ kg})(1500 \text{ m s}^{-1})^2 = 67500 \text{ kg m}^2 \text{s}^{-2}$$

$$K.E = 67500 \text{ J}$$

$\frac{1500}{2} = 750 \times 0.03$ 33750 J.

6.An object of mass (10 kg) is lifted vertically through a distance of (5 m) at a constant speed. What is the gravitational potential energy gained by the object ?

SOLUTION Mass of the object , m = 10 kg

Height of the object , h = 5 m

Value of acceleration due to gravity (gravitational acceleration) on the surface of the earth , g = 10 m s^{-2}

Potential energy gained by the body , P .E = ?

Using the equation

$$P.E = m g h$$

$$P.E = (10 \text{ kg})(5 \text{ m})(10 \text{ m s}^{-2}) = 500 \text{ kg m}^2 \text{s}^{-2}$$

$$P.E = 500 \text{ J}$$